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Effect of search window size on search and rescue call-around performance

Stuart C. Grant

Defence R&D Canada
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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

The Fixed Wing Search and Rescue (FWSAR) project tasked Defence Research and Development Canada (DRDC) to provide guidance on the primary search window requirements for a new SAR aircraft. At issue was the effect of the size and location of the SAR technician's window on the SAR technician's ability to verbally guide a pilot to fly the aircraft over a search object. An answer was obtained through a two-stage approach. First, data were collected using a simulation of the call-around. In the synthetic environment, six SAR technicians performed a large number of call-arounds where the search window size and observer position in a simulated aircraft were adjusted on a trial-by-trial basis. Then, a live flying trial at CFB Comox involving two SAR technicians was conducted to validate the results obtained from the synthetic environment. Three recommendations emerged. First, the primary search window should provide a field of view of at least 160°. Second, performance is not affected by the visual effect of placing the window ahead of, or behind, the wing. Third, to obtain the full benefit of the field of view afforded by the window, the observer must be provided with an ergonomically sound work station.

Résumé

Dans le cadre du projet d'avion de recherche et de sauvetage (SAR)à voilure fixe, R & D pour la défense Canada (RDDC) a été chargé de donner des conseils sur les exigences d'une fenêtre de recherche primaire pour un nouvel avion SAR. Ce qui était en cause, c'était l'effet de la taille et de l'emplacement de la fenêtre du technicien SAR sur la capacité du technicien à diriger de vive voix un pilote aux commandes de l'avion au-dessus de l'objet recherché. Une réponse a été obtenue au moyen d'une approche en deux étapes. Tout d'abord, des données ont été recueillies à l'aide d'une simulation d'appel général. Dans un environnement synthétique, six techniciens SAR ont effectué un grand nombre d'appels généraux au cours desquels la taille de la fenêtre de recherche et la position de l'observateur dans un avion simulé ont été réglés au cas par cas. Ensuite, un essai en vol réel auquel ont participé deux techniciens SAR a été mené à la BFC Comox en vue de la validation des résultats obtenus à partir de l'environnement synthétique. Trois recommandations ressortent. Premièrement, la fenêtre de recherche primaire devrait donner un champ de vision d'au moins 160°. Deuxièmement, la performance n'est pas touchée par l'effet, sur le champ de vision, de l'emplacement de la fenêtre à l'avant ou à l'arrière de l'aile. Troisièmement, pour tirer pleinement parti du champ de vision que donne la fenêtre, l'observateur doit disposer d'un poste de travail ergonomique.

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Executive summary

Effect of search window size on search and rescue call-around performance

Stuart C. Grant; DRDC Toronto TR 2007-162; Defence R&D Canada – Toronto; December 2007.

The Canadian Forces (CF) has established the Fixed Wing Search and Rescue (FWSAR) project to replace the CC-115 Buffalo and CC-130 Hercules aircraft currently assigned to the search and rescue (SAR) role with a new fleet of SAR aircraft. Despite advances in aircraft-mounted sensors, the primary search window will continue to be important in successfully executing the search and rescue mission. To assist in setting the requirement for the size of the window, FWSAR requested Defence Research and Development Canada (DRDC) to undertake studies relating the size and location of the window to performance in the SAR mission.

To provide advice to the FWSAR project, a two-stage approach was adopted. First, data were collected using a simulation of the call-around. In the synthetic environment, six SAR technicians performed a large number of call-arounds where the search window size and observer position in a simulated aircraft could be adjusted on a trial-by-trial basis. From these data, the relationship between observer field of view and call-around performance was determined. Then, a live flying trial at CFB Comox involving two SAR technicians was conducted to validate the results obtained from the synthetic environment.

The following recommendations are provided to the FWSAR project to assist in the requirements or selection of a new aircraft.

1. The primary search window should provide the observer with at least 160° field of view to enable the observer to attain their peak level of call-around performance. With this field of view, one can expect a probability of a successful call-around of at least .90 for four of six observers.

2. The positioning of the primary search window relative to the wing should be guided by factors other than the effect of the wing's position in the field of view during call-arounds. The fore/aft location of the window relative to the wing was not found to affect call-around performance.

3. When a field of view requirement is specified for a new SAR aircraft, it is critically important that the field of view be provided within the context of an ergonomically sound work station. A work station with poor ergonomics will undermine overall system performance.

The combination of the synthetic and live environments proved suitable for answering the questions posed by the FWSAR project. The apparatus will be maintained for one year to retain the capability to respond to similar requirements in the near future.

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Effect of search window size on search and rescue call-around performance

Stuart C. Grant; DRDC Toronto TR 2007-162; R & D pour la défense Canada – Toronto; Décembre 2007.

Les Forces canadiennes (FC) ont lancé le projet d'avion de recherche et de sauvetage (SAR) à voilure fixe pour remplacer le CC-115 Buffalo et le CC-130 Hercules présentement affectés à un rôle SAR par une nouvelle flotte d'avions SAR. En dépit des progrès réalisés dans les capteurs à bord d'avions, la fenêtre de recherche primaire conserve son importance pour la réussite des missions SAR. Pour contribuer à établir les exigences associées à la taille de la fenêtre, les responsables du projet d'avion SAR à voilure fixe ont demandé à R & D pour la défense Canada (RDDC) de mener des études au sujet de l'effet de la taille et de l'emplacement de la fenêtre sur la performance de la mission SAR.

Pour donner des conseils aux responsables du projet d'avion SAR à voilure fixe, RDDC a adopté une approche en deux étapes. Tout d'abord, des données ont été recueillies à l'aide d'une simulation d'appel général. Dans un environnement synthétique, six techniciens SAR ont effectué un grand nombre d'appels généraux au cours desquels la taille de la fenêtre de recherche et la position de l'observateur dans un avion simulé ont été réglés au cas par cas. À partir de ces données, le rapport entre le champ de vision de l'observateur et le rendement de l'appel général a été déterminé. Ensuite, un essai en vol réel auquel ont participé deux techniciens SAR a été mené à la BFC Comox en vue de la validation des résultats obtenus à partir de l'environnement synthétique.

Les recommandations qui suivent sont présentées aux responsables du projet d'avion SAR à voilure fixe en vue d'une meilleure définition du besoin ou de la sélection d'un nouvel avion :

1. La fenêtre de recherche primaire devrait donner à l'observateur un champ de vision d'au moins 160° pour lui permettre de donner son meilleur rendement en réponse à l'appel général. Ce champ de vision permet d'espérer une probabilité d'appel général réussi d'au moins 0,90 pour quatre observateurs sur six.

2. L'emplacement de la fenêtre de recherche primaire par rapport à l'aile devrait être guidé par des facteurs autres que l'effet de la position de l'aile dans le champ de vision durant des appels généraux. On a jugé que la position à l'avant ou à l'arrière de la fenêtre par rapport à l'aile n'influe pas sur la performance en réponse à un appel général.

3. Lorsqu'un champ de vision donné est précisé pour un nouvel avion SAR, il est critique qu'il soit fourni dans le contexte d'un poste de travail ergonomique. Un poste de travail mal conçu sur le plan ergonomique a pour effet de miner la performance générale du système.

La combinaison d'un environnement synthétique et d'un environnement réel paraît convenir pour répondre aux questions des responsables du projet d'avion SAR à voilure fixe. L'appareillage sera

conservé pendant un an pour maintenir la capacité de répondre à des besoins semblables dans un proche avenir.

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Acknowledgements

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1 Introduction

1.1 Background

The Canadian Forces (CF) has established the Fixed Wing Search and Rescue (FWSAR) project to replace the CC-115 Buffalo and CC-130 Hercules aircraft currently assigned to the search and rescue (SAR) role with a new fleet of SAR aircraft. Despite advances in aircraft-mounted sensors, the primary search window will continue to be important in successfully executing the search and rescue mission. To assist in setting the requirement for the size of the window, FWSAR requested Defence Research and Development Canada (DRDC) to undertake studies relating the size and location of the window to performance in the SAR mission.

Spotters on the SAR aircraft look through the primary search window at numerous points throughout the mission. Two tasks are of particular interest. The first task is the search, where the observers attempt to find the search object. The manner in which they scan the search region is described in DND's Spotter's Guide [1]. The effect of window shape and size on search performance has been addressed analytically for FWSAR [2].

The second task is the call-around. The call-around begins when the observer detects an object and then verbally provides course change instructions to the pilot that will result in the aircraft over-flying or approaching the target for further action. Because of the interactive and dynamic nature of this task, the decision was made to use experimentation to understand the relationship between window size and call-around performance.

Understanding the relationship between window size and call-around performance is important to setting aircraft requirements because there is a trade-off between window size and other aspects of mission performance. Although greater fields of view can be expected to aid call-arounds, installing large windows can affect structural strength of the airframe and preclude pressurization of the aircraft. For example, a very large window might lead to good call-around performance, but a lack of pressurization might require low, slow transits to the search area. The goal of the study was therefore to provide the FWSAR project office with an understanding of the relationship between window size and call-around performance. Using this information, the project can then make informed decisions concerning the trade-off of window size against other competing factors.

Conducting the experiment entirely using live flying was considered impractical. The large number of trials required to collect the necessary data would not be affordable and would take too much time from SAR personnel. Consequently, a two-stage approach was adopted. First, data would be collected using a simulation of the call-around. A synthetic environment was constructed that included a simulated SAR aircraft and a world where call-arounds on a search object could be performed. The search window at the observer position in the simulated aircraft could be adjusted on a trial-by-trial basis. By conducting a large number of call-arounds in the synthetic environment, a relationship between observer field of view and call-around performance could be calculated. Then, a live flying trial was conducted to validate the results obtained from the synthetic environment.

Finally, the synthetic environment was used to consider how the location of the search window, fore or aft of the wing, would affect call-around performance.

2 Synthetic environment experiment

2.1 Method

To economize on the time required from the research subjects and to make most efficient use of the data collection opportunity, the techniques of adaptive testing and parameter estimation from the field of psychophysics were adapted to relate field of view to call-around performance. The ZEST (zippy estimating by sequential testing) methodology [3] provides a fast method of determining thresholds in sensory experiments [4]. In a typical application of ZEST in a yes | no experiment, a test subject is repeatedly asked whether a weak stimulus, say a quiet tone, was presented. The strength of the stimulus is adjusted on a trial-by-trial basis, and a threshold is calculated as the stimulus strength that results in a probability of detection equal to a criterion level, such as 75%. The ZEST methodology adjusts the stimulus strength on a trial-by-trial basis, using the cumulative results for that subject to estimate the probability density function that describes the relationship between stimulus strength and probability of a correct response. In this trial, the ZEST method was used to determine the threshold field of view provided to the observer that would lead to a criterion level of performance on the call-around task.

Field of view can be defined by the angle visible above, below, left, and right of the line of sight. To make the problem of determining the effect of field of view on call-arounds more tractable, the following assumptions were made. First, the field of view above the line of sight from the observer window was fixed at 45°. This was done because the maximum normal bank angle for SAR aircraft is typically in the range of 45°, so a 45° upward field of view would allow an observer to maintain eyes on the horizon even during this typical bank angle situation. The field of view below the observer's line of sight was set to 89° downward. This was chosen because it approached the lower field of view that would allow observers to see directly beneath the aircraft from search altitudes. The field of view actually required to achieve overlapping downward fields of view at SAR altitudes from each side of the aircraft for this is 91° but that is beyond the limits of the apparatus. The horizontal field of view was allowed to vary for the purposes of the experiment, but it was constrained to be symmetrical, i.e., the angle to the left and right of the line of sight was the same. Finally, the observer eyepoint was oriented to look with 0° elevation and 90° aft of the aircraft centreline (i.e., looking level, directly out the side). The eyepoint was located 3 meters behind, 2.5 meters to the right, and 0.5 meters below, the aircraft's centre of mass. This placed the eye point on the right side of the fuselage, behind the wing, and approximately half way up the height of the fuselage. A wing was not visible in the observer's field of view during the field of view trials. During the trials investigating the location of the primary search window, a wing was present in the field of view, and the eyepoint was located 2 meters ahead of the forward edge of the wing, or 2 meters behind the trailing edge of the wing.

2.1.1 Subjects

Six subjects participated in the synthetic environment experiment. All were SAR Technicians with at least six months experience. The subjects voluntarily authorized the use of their data for the analysis and they were financially compensated in accordance with the CF Compensation and Benefits Instruction 205.48 and DRDC remuneration guidelines. This amounted to $31.65 per

subject. The experiments were conducted with the approval of the DRDC Human Research Ethics Committee.

2.1.2 Apparatus

The synthetic environment consisted of an observer station, a pilot station, and an instructor operator station. The observer station presented the observer with computer-generated imagery projected onto an Elumens Visionstation hemispherical screen. The VisionStation provided a field of regard of 178° horizontally and 135° vertically at the design eyepoint, which coincides with the location of the projector lens. The computer generated imagery was rendered using Meta VR's Virtual Reality Scene Generator Version 5.2a software. The rendering software used the correction algorithms provided by Elumens to properly employ the wide angle lens and curved screen of the VisionStation. The software created imagery from an eyepoint at the side of an aircraft (the aircraft is described in the pilot station paragraph below). The horizontal field of view was manipulated on a trial-by-trial basis. It is important to note that the changes in the field of view were consistent in the angle of the view generated and the angular size of the image projected. In other words, there was no magnification or minification in the geometry of the rendering. The observer's visual experience during changes to the field of view was that the sides of the window moved closer together or farther apart, not one of zooming in or out. It should also be noted that the field of view visible was determined by what was rendered by the software. The subject could not change the field of view by moving his head toward or away from the virtual window.

The observer was provided with a headset and a push-to-talk microphone switch that provided communications with the pilot.

The observer station is presented in Figure 1.

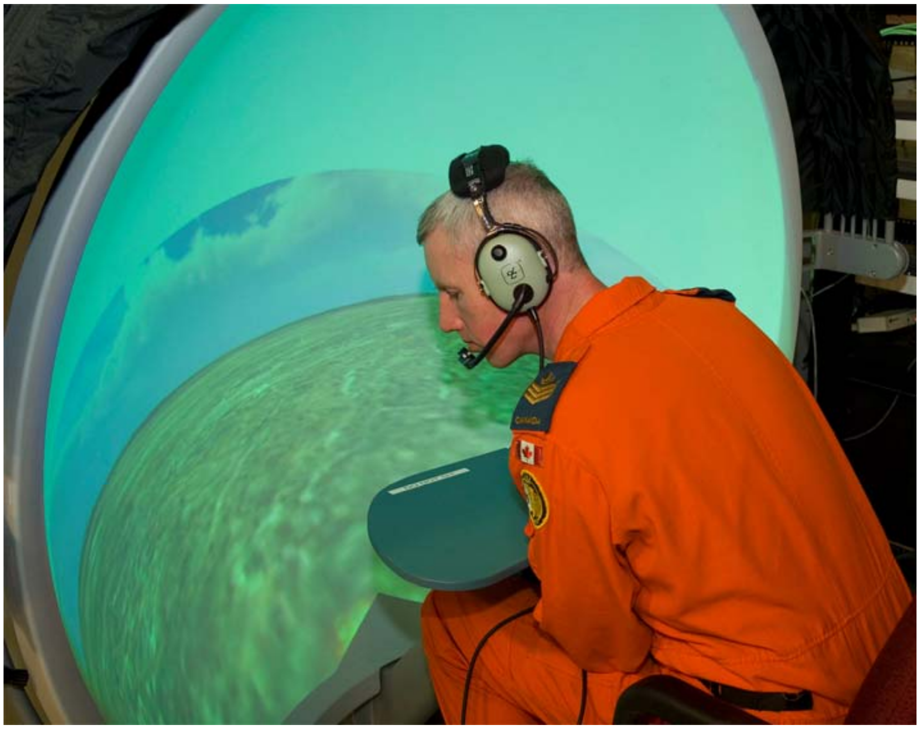

Figure 1 The Observer Station

The pilot station consisted of a flight simulator and communications system. The flight simulation was X-Plane version 8.4. The simulation ran a model of a C-130J aircraft to enable the pilot to easily fly a flight profile that showed the airspeeds, altitudes and roll rates typical of a SAR mission. Additional software was written to allow the simulation to send the aircraft's position and velocity information over a computer network to the observer station using a subset of the Distributed Interactive Simulation version 2.0.4 / IEEE 1278.1 protocol. The pilot input devices were a yoke, pedals, and throttles. The pilot had a single screen view of the world and instruments.

The absolute fidelity of the C-130J model in the simulation was not important because the requirements of the experiment did not require the representation of any aircraft in particular, only that the eyepoint of the observer must be able to attach to an aircraft following a typical SAR mission flight profile.

The pilot was provided with a headset and a push-to-talk microphone switch that provided communications with the observer.

The pilot station was operated by a CF member who is a licensed multi-engine pilot. The pilot was provided with the attitude, speed, and turns used in the SAR mission and an experienced SAR pilot coached him in his flying of this profile.

The pilot station is presented in Figure 2.

Figure 2 The Pilot Station

The instructor operator station provided a graphical user interface to stop, start, configure, monitor, and record the trials in the synthetic environment. The instructor could adjust the size and location of the field of view in a continuous manner during run time. The system allowed the initial conditions for each trial run to be loaded from a file or set in real time. It also provided real time feedback on the position of the SAR aircraft from the search object, with a configurable indicator that would show success or failure to achieve the trial objective. The system also contained a repeater monitor showing the view visible to the observer. The instructor operator station is presented in Figure 3.

Figure 3 The Instructor Operator Station

The search object that was the target for the call around was a model of a crashed C-130 aircraft. To ensure that the observer's performance was not affected by the need to detect the target, the crashed aircraft was depicted as burning, with a large column of animated fire. The aircraft model and SAR flight took place on a visual terrain database depicting the American south-west. The target was placed in relatively featureless areas of southern Utah to prevent the observers from using landmarks such as roads or lake edges to maintain a fix on the target when it left their field of view. The visual terrain databases were different, although well correlated, for the pilot and observer stations. However, the pilot view never displayed the search object, so the success of the call-around depended on the visual contact made by the observer.

2.1.3 Procedure

Each subject began their session with a briefing that included obtaining informed consent for the use of his data, a briefing on the simulated SAR mission, and collection of Simulator Sickness Questionnaire data [5]. Following the briefing, the subjects completed the field of view trials. Upon completing the field of view trials, subjects completed the window location trials. The subjects concluded their participation with a final administration of the Simulator Sickness Questionnaire.

The Simulator Sickness Questionnaire was administered before and after using the synthetic environment to determine if the subject experience adverse effects from participation. No subjects suffered elevated symptoms, so these results will not be subsequently reported.

The SAR mission briefing was delivered by the pilot and the experimenters. The briefing explained that the mission would be flown at an altitude of 1500 feet and a speed of 130 knots. The observer was informed that the search range was 3 nautical miles (nm), although each trial would begin with the search object detected and within 3 nm. The time of day in the simulated environment was 1200 hours, and the weather visibility was unlimited. The observers were told

that they would be observing from the right side of the aircraft and they were shown a picture of the search object. They were instructed that they should give call-around information to the pilot to fly directly over the target. The pilot would not be able to see the search object, so the observer was to concentrate on calling the aircraft through the entire over-flight and not try to talk the pilot's eyes onto the search object. Bank angles of 15°, 30° and 45° would be called as easy, standard, and hard turns, respectively. The pilot and observer then had a conversion to confirm mutual understanding of the conning instructions. Following an explanation of how the trials would be conducted, any questions posed by the subject were answered and the field of view trials began.

2.1.3.1 Field of view trials

The field of view trials were structured into four blocks of ten trials each. Between each trial the subject was prompted to take a break of whatever duration the subject desired. Prior to the four blocks of trials, the subjects were given two practice trials to familiarize themselves with the apparatus and the procedure.

Each trial began with the simulation paused, and the aircraft at an altitude of 1500 feet above ground level and a speed of 130 knots. The search object was always at a range of 3 nm, and between one and two miles off the track of the aircraft, on the observer's side. The location of the search object and aircraft changed on a trial-by-trial basis so that patterns on the ground or timings of turns could not be memorized and reused to perform the task. The experimenter would confirm that the subject had detected the search object and was ready to begin the trial. The trial was started when the subject indicated he was ready.

As the aircraft manoeuvred to attempt to overfly the search object, the instructor / operator monitored the range to the search object. If the aircraft came within the criterion distance, the trial was scored as a success. If the closest point of approach was not within the criterion distance, the subject was instructed to "go around." The subject would then reposition and make a second attempt to overfly the target. If the aircraft came within the criterion distance, the trial would be scored as a success, otherwise it was a failure.

The criterion for success was set at 500 feet. It was set at this value due to the limited downward look angle provided by the Elumens display. By setting the criterion at this value, the search object would be visible, moving along the bottom edge of the display, when the aircraft was at the set criterion. This distance is greater than normally desired in a SAR overflight. This discrepancy was judged as acceptable because, once an aircraft comes within 500 feet of the search object, there is insufficient time for the subject to make a new conning call, the pilot to make the control inputs, and for the aircraft to change direction. Also, the downward field of view of the future FWSAR aircraft will likely be set by other system requirements.

On the first trial, the field of view was set to 178°. On successful trials, the field of view then was decreased on the next trial. Unsuccessful trials resulted in the field of view being increased. The actual amount of the change in the field of view was calculated using the ZEST method [3,4] to obtain the most informative test value. The ZEST algorithm was set to estimate the mean of probability density function for fields of view that would provide a 0.9 probability of a successful overflight. The initial estimate of the mean provided to the ZEST algorithm was 178°.

2.1.3.2 Window location trials

Following the field of view trials, the subject was given a rest break of at least five minutes. Then twenty additional trials were conducted to assess the effect of the search window location on call-around performance. An aircraft wing was now included in the view provided to the subjects. In one block of ten trials, the subject's eye point was positioned 2 meters ahead of the wing's leading edge. In the other block of ten trials, the eye point was 2 meters behind the trailing edge. The order of placing the eye point fore and aft of the wing was counterbalanced across subjects. The field of view was fixed at the optimal location for that subject as determined by the ZEST method during the field of view trials. The procedure was otherwise the same as that for the field of view trials.

2.2 Results

The subjects were able to successfully perform call-arounds in the synthetic environment. Due to time limitations, Subject #1 was able to complete only 20 field of view trials. That subject's results were retained and analyzed.

The data were sorted into bins of 10°, and the proportions of successful call-arounds performed by each subject at those fields of view were computed. These results are reported in Table 1. Not all subjects attempted call-arounds at all fields of view, due to the adaptive nature of the testing. In those cases, the cell in the table is left empty.

Table 1 Proportion of Successes obtained by each Subject

	Subject					
FOV	**1**	**2**	**3**	**4**	**5**	**6**
85						0
95		.333				.667
105	.5	1		.5		.9
115		.8	0	1		1
125	1	.867	1	.909		1
135	0	1	.6	1		1
145	1	1	.778	1		1
155		1	1		0	1
165	1	1	1		.875	1
175	.75	1	.923	1	.8	1

FOV = Field of View

For each subject, the ZEST algorithm reported the mean and standard deviation of the probability density function for fields of view that would provide a 90% chance of a successful over flight. These results are presented in Table 2.

Table 2 Estimated Field of View Required to Attain .9 Probability of Success

	Subject					
	1	**2**	**3**	**4**	**5**	**6**
Mean (degrees)	256	124	154	114	198	103
Standard deviation (degrees)	8.32	4.2	4.28	4.48	5.00	4.20

Using the estimated fields of view obtained in the experiment, the mean field of view for the overall SAR Technician population was calculated to be 158° with a standard error of the mean equal to 24°. The 90% confidence interval was calculated to be 158° ± 1.65 x 24° = 118° - 198°. That is, there is a 0.9 probability that the average field of view required by the CF's SAR Technicians to obtain the stated level of performance falls between 118° and 198°, with the best estimate being 158°.

The data from all subjects were also sorted into 5 degree bins and the probability of success plotted. The field of view estimate for each subject is plotted in Figure 4. At relatively narrow fields of view, high probabilities of success were observed, but these data points are derived from the subjects who were successful enough to attempt the task under such difficult conditions.

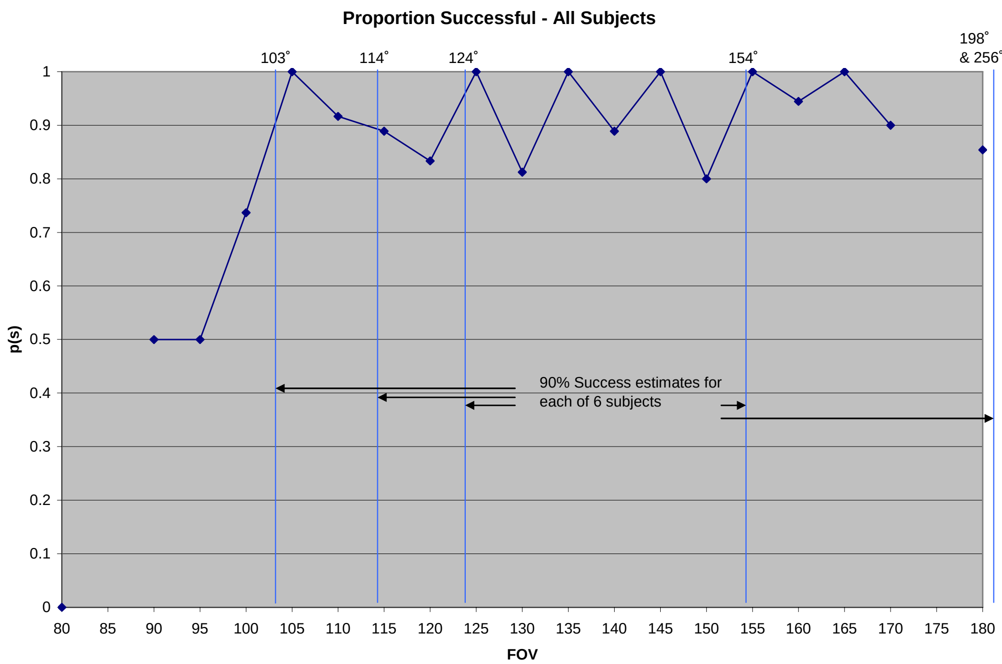

Figure 4 Proportion of successes, p(s,), versus field of view (FOV) with individual 0.9 success rates

Finally, a logit model [6] of the probability of a successful call-around as a function of field of view was fitted to the data. Logit models are used when predicting binary data (i.e success or failure of the call-around) from continuous predictors (i.e. field of view). Logit models are usually constrained to converge to an upper probability of 1.0. In this experiment, however, factors other

than field of view could potentially prevent perfect performance, such as pilot error, communications failure, etc. Therefore an additional parameter was allowed in the model that would allow the model to asymptote below a probability of 1. The fitted model was

$$p(s) = \frac{m}{1 + e^{-(b_0 + b_1 FOV)}},$$

where m is the maximum performance level, b_0 moves the curve along the X-axis, and b_1 indicates how quickly performance changes with field of view (FOV). The data were sorted into 10 degree-wide bins and the model was fit to the data using a least square error criterion. The resulting fit, illustrated in Figure 5, was good, $R^2 = 0.96$. The obtained parameter values were $m = 0.872$, $b_0 = -34.362$, and $b_1 = 0.367$. It should be remembered, however, that the fit of the model is overestimated. The adaptive nature of the testing resulted in fewer or no data points from some subjects at the narrower fields of view.

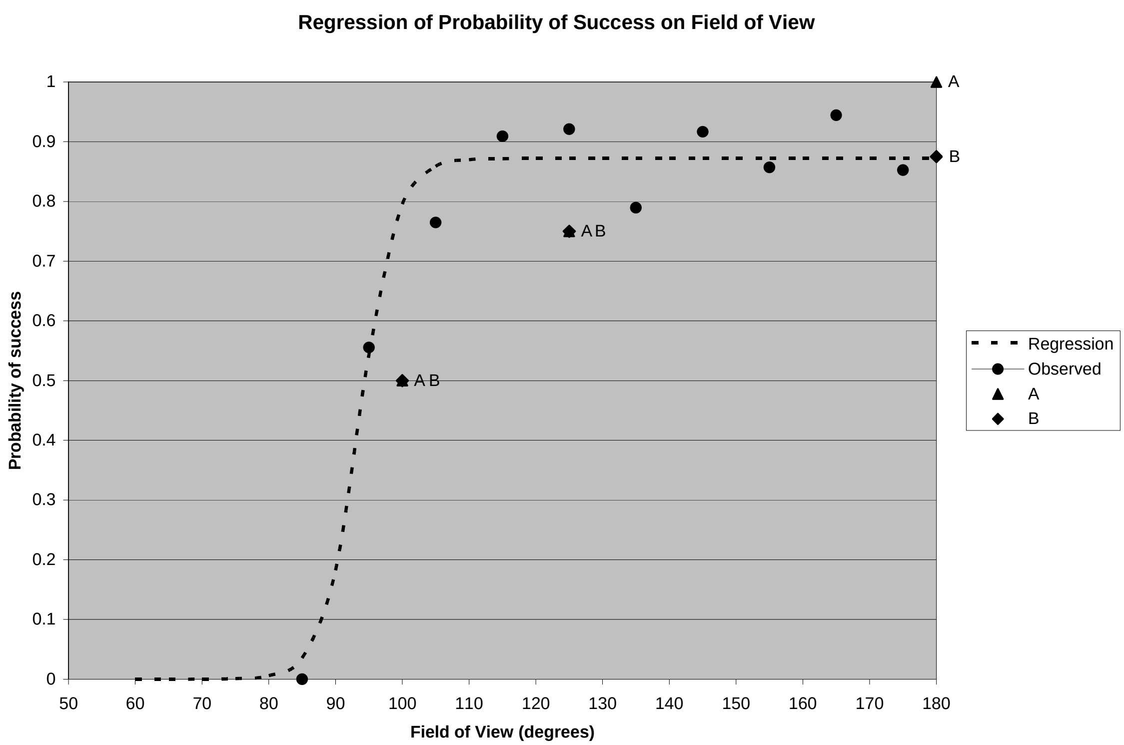

Figure 5 Logit regression model fit to data observed in the synthetic environment and from Subjects A and B in the Live Fly experiment

The window location trials considered the number of successful call-arounds based on the location of the window. The results are presented in Table 3.

Table 3 Number of Successfull Call Arounds, out of 10

Subject	Window Forward of Wing	Window Aft of Wing
1	6	9
2	10	9
3	10	10
4	9	9
5	10	10
6	10	10

The results indicated that only one subject showed a difference between forward and aft locations. Not surprisingly, a paired sample t-test did not reveal a reliable difference between window locations, t (5) = 0.59, p > .05.

2.3 Conclusions

The subjects were able to perform the task in the synthetic environment. Their results indicate that there was some variability in the subject's performance. Two of the subjects would not be able to reach the target probability of success of 0.9 even with a 180° field of view. They reached their peak level of performance between 140° and 170°, in the case of Subject 1, and 160° to 170° for Subject 5. The others subjects could reach the 0.9 standard at fields of view ranging from 103° to 154°.

Different presentations of the data lead to similar findings. To characterize the results roughly, at fields of view below 120°, performance is unreliable and deteriorates rapidly. Between 120° and 160°, performance becomes much more reliable, and above 160°, performance remains near the ceiling.

Locating the window 2 meters forward of the aircraft wing versus 2 meters behind the wing did not affect performance in the call around task.

3 Live flying experiment

The results from the experiment in the synthetic environment indicated that most of the subjects could have a high probability of successfully calling around the aircraft when working with a field of view less than 180°. In fact, half of the SAR Technicianss could perform a call-around with a probability of success ≥ .9 with a 124° field of view. To validate these results, a live flying trial was conducted. If the results obtained in the synthetic environment are valid, SAR Technicians should be able to successfully make call-arounds with a field of view of about the 124° identified in the synthetic environment experiment. A substantially greater field of view should provide limited benefit, whereas a narrower field of view should provide a substantial decrement to performance.

3.1 Method

About 400 trials were run in the synthetic environment, many more than are feasible in live flying. Therefore, a different approach was adopted. Three fields of view were considered: 100°, which was just less than the field of view required by the best performing SAR Technician in the synthetic environment, 125°, which was satisfactory for half of the SAR Technicians, and 180°, which is the maximum easily available in the bubble window of test aircraft, the CC-115 Buffalo.

In a further concession to the costs of flight time, only two SAR Technicians were used as subjects in the live flying experiment. Ultimately, 48 trials were possible.

3.1.1 Subjects

Two SAR Technicians assigned to 442 Squadron, with at least six months operational experience as SAR Techs served as subjects. 442 Squadron operates the CC-115 Buffalo aircraft, and the subjects were familiar with SAR operations on that aircraft.

Although a larger sample size would have been preferred because it would have allowed the parameters to be estimated with smaller confidence intervals, the operational tempo of the supporting unit and aircraft availability prevented this from happening. The analysis section provides variances and error estimates that provide 90 % confidence intervals based on the available data.

3.1.2 Apparatus

The subjects flew on the CC-115 Buffalo aircraft. The rest of the aircrew were CC-115 aircrew from 442 Squadron. The aircraft flew a SAR profile, at 1500 feet altitude. The pilots were instructed to manoeuvre the aircraft in response to the call-around instructions from the observer as they normally would, with the exception that the pilots should rely entirely upon the call-around instructions rather than assuming control of the manoeuvre once they see the search object themselves.

The Buffalo is a SAR aircraft equipped with a bubble search window. By controlling the distance of the subject's eye from the window, it was possible to control the field of view available. To do

this, a wire of a fixed length was attached to either side of the bubble window at the widest point and the subjects were instructed to hold the mid-point of the wire away from the window and to place their chin at the mid-point. By varying the length of the wire, it was possible to restrict the field of view to 100°, 125°, or 180° (see Figure 6).

Figure 6 The wire apparatus used to control field of view

The search object was the Station 46131 Sentry Shoal 3-meter discus buoy (see Figure 7), located near CFB Comox. The buoy recorded environmental conditions during the trial. Horizontal wind speed varied from approximately 5 – 10 meters per second. The characteristic significant wave height varied between 0.3 and 0.5 meters.

Figure 7. A 3 meter discus buoy, the type at Station 46131 Sentry Shoal

The position of the aircraft and the search object were measured and recorded using a Lowrance Airmap 2000c aviation global positioning system (GPS) terminal. The GPS was configured to display proximity to the search object and this information was used to determine success of each trial.

3.1.3 Procedure

The experiment began with an explanation of the goals of the experiment and obtaining informed consent from the subjects for the use of their data. The aircrew then completed a flight briefing and commenced the flight.

The flights were completed over two days. Each day began with a familiarization run and storage of the search object location in the GPS. Each subject was given two practice call-arounds prior to the start of the experimental trials.

Each subject completed 24 call-arounds. Each subject would complete one call-around at each field of view, 100°, 125°, and 180°, and then rest while the other subject completed three call-

arounds. This was done eight times, with the different fields of view being presented in a different order from one sequence to the next.

After each trial, the aircraft would extend to at least three miles from the search object and set up again to place the search object on the subject's side of the aircraft, within the search distance. The pilots were not informed which field of view was being tested on each particular trial.

The success criterion was 200 feet. Otherwise, the scoring procedure was unchanged from the synthetic environment experiment.

3.2 Results

Both subjects completed all of the experimental trials. The results of Subjects A and B are presented in Tables 4 and 5, respectively. The closest point of approach (CPA) values are the means of eight observations at each field of view, with the exception of Subject A with a 100° field of view. That value was computed from only seven observations because the subject lost track of the target location and the trial was halted.

Table 4 Closest Point of Appraoch (CPA) and Successes for Subject A

	Field of View		
	100°	**125°**	**180°**
CPA mean (feet)	199	131	145
CPA s.d. (feet)	136	92	57
Number of Successes	4	6	8
p (success)	.5	.75	1

Table 5 Closest Point of Appraoch(CPA) and Successes for Subject B

	Field of View		
	100°	**125°**	**180°**
CPA mean (feet)	219	198	138
CPA s.d. (feet)	103	198	79
Number of Successes	4	6	7
p (success)	.5	.75	.875

Based on the over flight data obtained solely through call-arounds, the estimate of the mean CPA achievable with 100° field of view is 209 feet, and a 90% confidence interval of 145 – 272 feet. The estimated mean CPA achievable with a 125° field of view is 165 feet, and a 90% confidence interval of 0 – 375 feet. The estimated mean CPA achievable with 180° is 141 feet, with a 90% confidence interval of 118 – 165 feet.

The proportion of successes obtained at each field of view for each subject is also reported in Tables 4 and 5. The results obtained by the two subjects are very similar. Their results were then plotted along with the regression line depicted in Figure 5. The limited number of data points

available in the live fly experiment, eight observations per subject at each field of view, restrict the possible proportions of success to steps of 0.125 (i.e. 1/8, 2/8, etc.). As a result, it is difficult to assess the goodness of fit of the model to the live fly data, particularly at the 100° field of view, where the curve changes so rapidly.

3.3 Conclusions

The live flying experiment found that the subjects could perform the task with varying degrees of success. Not surprisingly, the greater the field of view, the greater the probability of a successful call-around. When provided with a 100° field of view, the SAR Technicians could direct a successful overflight only half of the time. With a 125° field of view, they could do it three quarters of the time. A 180° field of view provided nearly perfect performance.

These performance levels correspond well with the values obtained in the synthetic environment. In the synthetic environment, only 1 of the 6 SAR Techs could perform well with a 103° field of view. Three of the six could perform well with a 124° field of view, and only two could not achieve a high degree of success with 178° field of view. The results obtained in the synthetic environment can be taken as representative of performance in the real environment.

Averaged across the two subjects, the closest point of approach observed under each of the fields of view shows the same gradient. One exception is that Subject A showed a smaller CPA with 125° than with 180°.

4 Conclusions and recommendations

The two experiments in this study were conducted to assist the FWSAR project is setting field of view requirements for a new aircraft. Specifically, the effect of primary search window size on call-around performance was investigated. The effect of locating the search window ahead of, and behind, the wing was also considered. An experiment in a synthetic environment was conducted to collect extensive data on a variety of possible fields of view and two window locations. A follow-on live-flying experiment validated the results obtained in the synthetic environment.

4.1 Conclusions

This study attempted to estimate the field of view that would provide a probability of successful call-around in two attempts equal to 0.90. For half of the SAR Technicians (three of six tested), a field of view equal to 124° was sufficient to meet this criterion. Four of the six technicians could reach the standard when the field of view was 154°. The other two technicians could not reach the standard even with a field of view equal to 180°. The average of these values is 158°. The two subjects who did not achieve a stable level of performance of at least 0.9 reached their peak level of performance (at least 0.8) with the field of view at or below 170°.

The synthetic environment did not reveal a differential effect of the visual occlusion caused by the aircraft wing on call-around performance. Call-around performance was unchanged when the search window was located an equal distance forward versus aft of the wing.

There are two limitations in these experiments that should be considered when applying the conclusions. On the one hand, visibility in the synthetic environment was good which might cause performance levels to be overestimated. It was clear weather in the middle of the day. The weather during the live flying event was overcast with some rain, but not representative of the worst weather a SAR aircraft can be expected to encounter. On the other hand, other conditions of the experiment suggest that performance will likely be underestimated. First, only one SAR Technician was available to keep eyes on the search object during the call-around. Operationally, it is likely that more than one SAR Technician would put eyes on a potential search object once a call is made. Second, the pilots in both experiments were prohibited from taking over the call-around by using their own sight of the search object. Normally, the pilots would attempt to obtain visual contact with the search object from their location to improve the execution of the call around and overflight. Finally, the area surrounding the search objects were selected to be featureless and no marking aids were permitted. Operationally, the presence of ground features assists in the call-around and if they are absent, markers released from the aircraft can be used instead. Addressing these limitations could be the topic for future investigations.

4.2 Recommendations

1. If a FWSAR aircraft with a search window providing less than 120° field of view is considered by the project, the project should anticipate call-around performance being unreliable. Fields of view between 120° and 160° provide increasingly reliable call-around performance. The primary search window should provide the observer with at least 160° field of view to enable the observer to attain their peak level of call-around performance. With this field of view, one can expect a probability of a successful call-around of at least 0.90 for four of six observers.

2. The positioning of the primary search window relative to the aircraft wing should be guided by factors other than the effect of the wing's position in the field of view during call-arounds. The fore/aft location of the window relative to the wing was not found to affect call-around performance. Other factors, such as habitability, workflow, and aircraft loading for example, should be the more important factors in deciding the positioning of the search window ahead of, or behind, the wing.

3. When a field of view requirement is specified for a new SAR aircraft, it is critically important that the field of view be provided within the context of an ergonomically sound work station. A work station with poor ergonomics can reduce the performance of the observer provided with a particular field of view and it can reduce the nominal field of view. For example, a window that prevents an observer wearing a flight helmet from positioning his/her head in the window, may force the observer to remain farther from the window than the design intended, thus effectively reducing the field of view. Also a work station design that requires the observer to adopt straining postures to obtain the design's intended field of view will lead to excessive fatigue, injuries, or adopting less demanding postures that reduce the effective field of view. All of these will undermine performance.

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List of symbols/abbreviations/acronyms/initialisms

CF	Canadian Forces
CPA	Closest Point of Approach
DND	Department of National Defence
DRDC	Defence Research and Development Canada
FOV	Field of View
FWSAR	Fixed Wing Search and Rescue
GPS	Global Positioning System
OPI	Office of Primary Interest
SAR	Search and Rescue
SAR Tech	Search and Rescue Technician
ZEST	Zippy Estimating by Sequential Testing

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The Fixed Wing Search and Rescue (FWSAR) project tasked Defence Research and Development Canada to provide guidance on the primary search window requirements for a new SAR aircraft. At issue was the effect of the size and location of the SAR technician's window on the SAR technician's ability to verbally guide a pilot to fly the aircraft over a search object. An answer was obtained through a two-stage approach. First, data were collected using a simulation of the call-around. In the synthetic environment, six SAR technicians performed a large number of call-arounds where the search window size and observer position in a simulated aircraft were be adjusted on a trial-by-trial basis. Then, a live flying trial at CFB Comox involving two SAR technicians was conducted to validate the results obtained from the synthetic environment. Three recommendations emerged. First, the primary search window should provide a field of view of at least 160°. Second, performance is not affected by the visual effect of placing the window ahead of, or behind, the wing. Third, to obtain the full benefit of the field of view afforded by the window, the observer must be provided with an ergonomically sound work station.

Dans le cadre du projet d'avion de recherche et de sauvetage (SAR)à voilure fixe, R & D pour la défense Canada (RDDC) a été chargé de donner des conseils sur les exigences d'une fenêtre de recherche primaire pour un nouvel avion SAR. Ce qui était en cause, c'était l'effet de la taille et de l'emplacement de la fenêtre du technicien SAR sur la capacité du technicien à diriger de vive voix un pilote aux commandes de l'avion au-dessus de l'objet recherché. Une réponse a été obtenue au moyen d'une approche en deux étapes. Tout d'abord, des données ont été recueillies à l'aide d'une simulation d'appel général. Dans un environnement synthétique, six techniciens SAR ont effectué un grand nombre d'appels généraux au cours desquels la taille de la fenêtre de recherche et la position de l'observateur dans un avion simulé ont été réglés au cas par cas. Ensuite, un essai en vol réel auquel ont participé deux techniciens SAR a été mené à la BFC Comox en vue de la validation des résultats obtenus à partir de l'environnement synthétique. Trois recommandations ressortent. Premièrement, la fenêtre de recherche primaire devrait donner un champ de vision d'au moins 160°. Deuxièmement, la performance n'est pas touchée par l'effet, sur le champ de vision, de l'emplacement de la fenêtre à l'avant ou à l'arrière de l'aile. Troisièmement, pour tirer pleinement parti du champ de vision que donne la fenêtre, l'observateur doit disposer d'un poste de travail ergonomique.

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Search and Rescue; FWSAR; psychophysics; window; simulation;

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